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Determination of Water Quality, Water Use Efficiency, and Water Runoff in Pot-in-Pot Nurseries

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Introduction

In nursery production, the application of pot-in-pot systems has expanded rapidly during the last decade. Using the pot-in-pot system offers several advantages:

- Can moderate root temperature.
- Improves root quality.
- Protects trees from root-killing heat on container side walls.
- Prevents extreme temperature changes during the winter.
- Can help prevent the blowing over of container-grown trees from the wind.
- Can reduce intensive harvesting labor costs compared to field-grown tree production.

The disadvantage of the pot-in-pot system is that it restricts root spread for extraction of nutrients and water. To compensate for the disadvantage, it is essential to apply supplemental fertilization to satisfy nutrient requirements and sufficient water two or more times throughout a day to sustain rapid growth of trees (Beeson and Gilman, 1995; Ruter, 1997). However, due to these irrigation and fertilization practices, there have been concerns about water-use efficiency and the extent of nutrient and chemical leaching from irrigation and rainfall to the soil and ground water.

To fully explore potential impacts of the pot-in-pot production system on nursery production, knowledge of water quality and quantity to produce healthy trees is needed to improve application efficiency and reduce the potential of soil and groundwater contamination. For this purpose, we established a research project in cooperation with Willoway Nurseries, Inc., at Avon, Ohio, to:

- Determine the amount of leachate in pot-in-pot nurseries due to different levels of spray tube irrigation and rainfall.
- Determine levels of nutrient and pesticide residues in leachate with various irrigation schedules and pesticide spray application methods.
- Determine the relationship between the amount of irrigation and soil moisture

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content in individual pots before and after leaching of water.

- Determine the relationship among soil moisture content, soil temperature, and tree growth rate.

Materials and Methods

An experimental system (Figure 1) to examine water quality, irrigation efficiency, and water runoff was established in a plot in Willoway Nurseries, Inc., in 2003. The system mainly consisted of a plot containing 50 trees planted in 50 pot-in-pot containers and irrigated with micro-spray emitters, 10 water runoff collection devices, 10 soil-moisture sensors, 10 thermocouples, a weather station, and a data logger.

Factors examined in this study were total amounts of irrigation, rainfall, and leachate from the plot; start and stop times for leaching; types of trees; soil-moisture content; soil temperature; and chemical residue levels, precipitation, and other weather conditions.

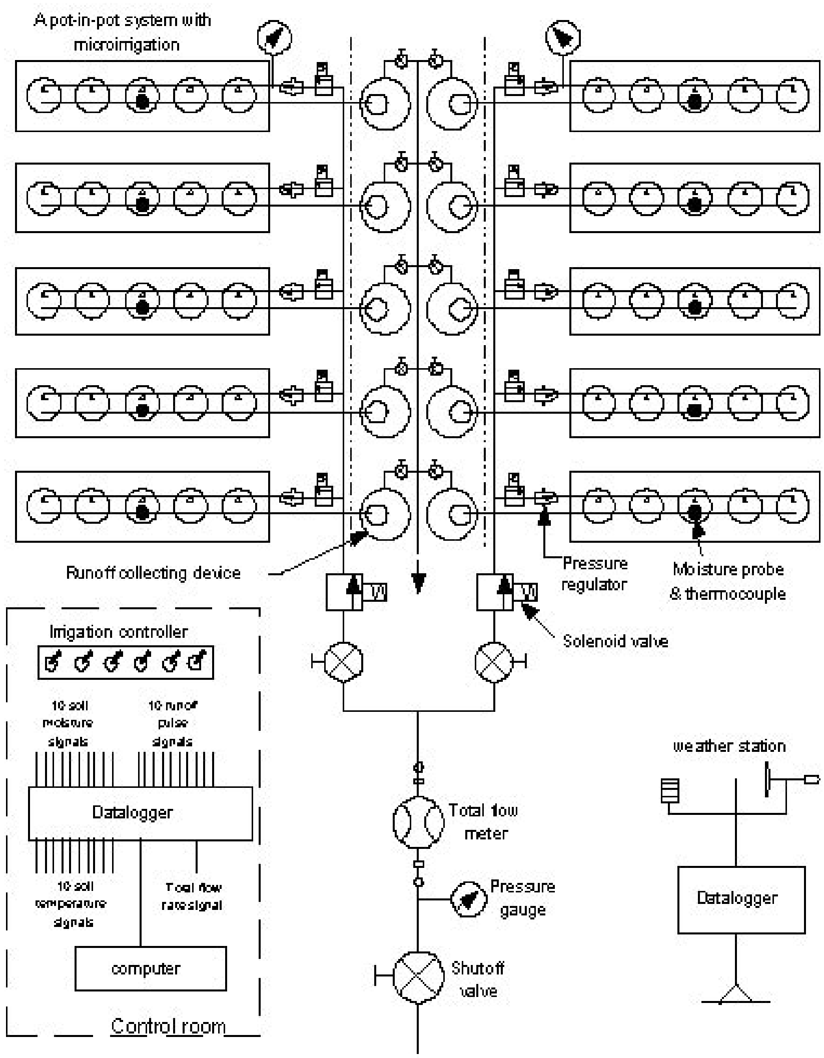

Figure 1. The experimental plot established to determine water quality and quantity for pot-in-pot nurseries

Pot-in-Pot Production Plot

The pot-in-pot production plot was divided into two separate zones (Figure 1). Each zone had five beds, and each bed had five pots of trees in containers. Spacing between each two beds was 1 m, and spacing between each two trees was 1.5 m.

A production container for trees had 15-gallon capacity and was placed in a socket container. The socket container was installed in the ground to the rim of the container. The Red Sunset maple (*Acer rubrum* 'Franksred') was selected for the test. The average tree caliper was 1.4 cm (0.55 inches) when installed on July 3, 2003.

The plot was irrigated with Netafim micro-spray emitters. Each pot had one emitter installed near the container side wall to ensure that all of the water applied spread evenly within the container. Each bed had an irrigation supplying line with a 7 kPa pressure regulator to minimize variations in application rate.

A solenoid valve was also installed before the regulator at the beginning of the irrigation line to control the irrigation schedule for each bed. A manual gate valve and a solenoid valve were installed in the water supply line to each zone. A Fluidyne Model 1200 inline vortex flow rate meter was used to measure the total flow rate and the total amount of water applied to trees in two zones. Irrigation management was controlled with micro-switches in a control room (Figure 1).

Water Runoff Measurement

A Spectrum Technologies Model 3665R "tipping bucket" rain gauge was installed 0.43 m below the soil surface (Figure 2) to measure the amount of water runoff from five tree containers in each bed. A total of 10 rain gauges was used for 50 container trees in 10 beds. The gauges were calibrated with both tap water and leaching water collected from the runoff.

The rain gauge was used because the amount of water runoff from five containers was very low, and there were no inexpensive electronic flow meters available for such a dripping measurement. A 5 cm (2-inch) PVC pipe was installed 7 cm under five containers in each bed and extended to a 0.6 m diameter and 1.2 m deep sump. The PVC pipe was connected to the socket container with a grommet and a street tee (Figure 2).

Once the rain gauge collected 7.5 ml of water leached from the five containers, it would produce a pulse signal to the data logger. The data logger tracked the real time when it received the pulse signals from the rain gauge. A manual shutoff valve was installed under the sump to drain the leached water to an adjacent pond. A water sample in each sump was collected every week for water quality analysis by USDA-ARS North Appalachian Experimental Watershed Lab in Coshocton, Ohio.

Soil Moisture and Temperature Measurement

The potting soil moisture was measured with 10 Theta Probe type ML2X soil-moisture sensors. Each bed had one sensor installed 5 cm below the soil surface in the middle container. The sensors were placed 45° in the potting soil and 5 cm from trees. The sensors were calibrated with the tree mix potting soil and the water containing 200 ppm of nitrogen at the moisture content ranging from 5% to 60%. Soil temperatures adjacent to moisture probes were also measured with 10 thermocouples.

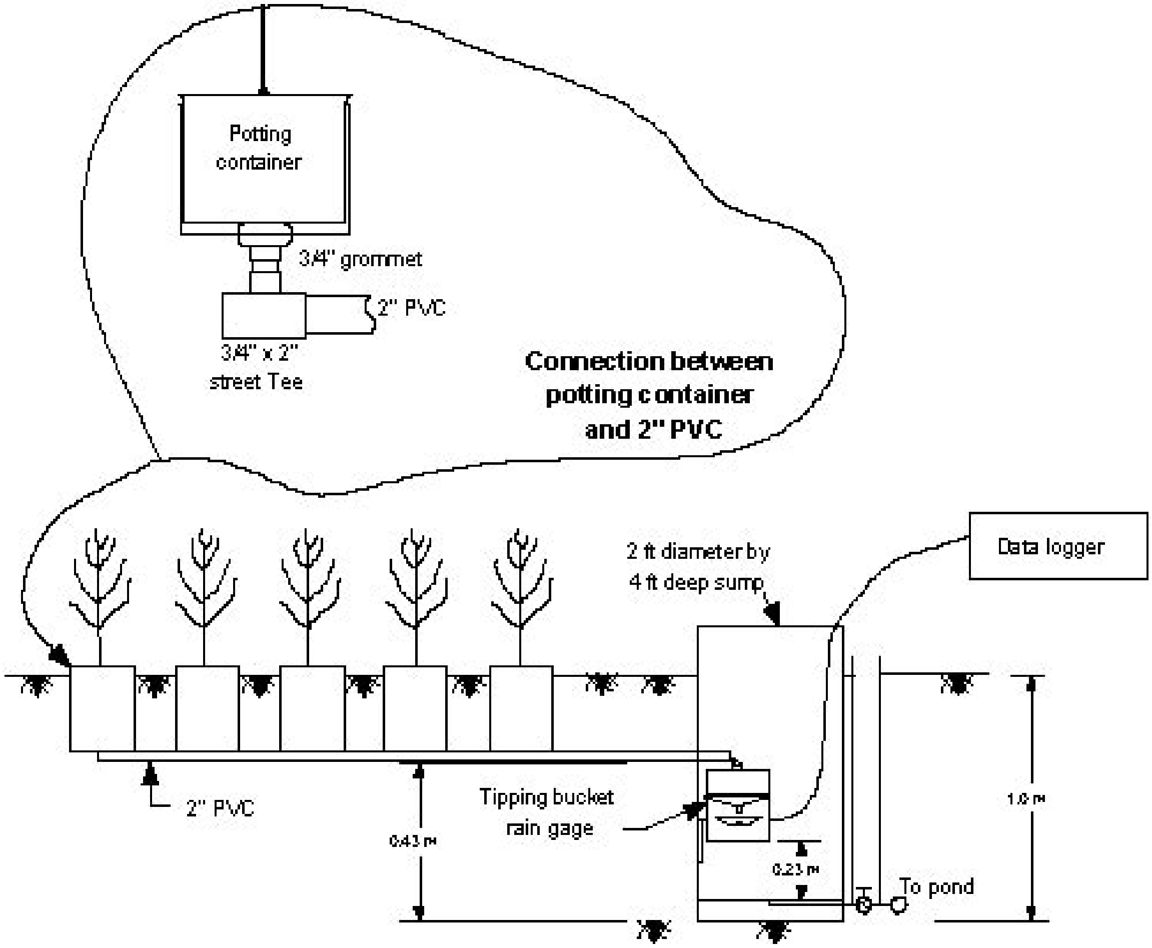

Figure 2: Diagram of the system to determine the amount of water runoff from five potting containers.

Weather Station

A moveable weather station equipped with a Campbell Scientific CM-6 system was installed near the experimental plot to measure precipitation, air temperature, relative humidity, solar radiation, atmospheric pressure, wind speed, and azimuth. The data are available on a network web site.

Data Collection

A Campbell Scientific CR23X data logger was used to process and acquire data from 10 rain gauges, 10 soil-moisture sensors, 10 thermocouples, and the total flow rate meter. The data logger was connected with two synchronous communication modules to allow multi-signal inputs simultaneously. The system collected data from rain gauges, moisture sensors, and thermocouples once a minute, while the total flow rate was collected each second only during the irrigation period.

Results and Discussion

The major goals for the year 2003 were to establish the experimental system and test the system reliability and accuracy for measuring water runoff, soil moisture, and temperature along with water chemical content and the relationship between water inputs and tree growth. After the system was established in July 2003, data were collected on the amount of irrigation, water runoff, soil moisture, soil temperature, weather conditions, and tree caliper 18 cm above the soil surface. The leaching level of some chemical residues such as nitrogen (N), phosphate (P), and potassium (K) in water runoff were also detected weekly from water samples.

Preliminary test results indicated that the amount of water runoff varied with irrigation rate, tree sizes, and potting soil density. The average amount of weekly water runoff from each container was 0.27 L during the period of time between August 6 and August 26 when the average application rate was 1.0 L per day.

During the period of time between August 27 and September 16, we increased the daily application rate to 2.4 L in order to compare the runoff level with the previous application rate. Under this situation, the average weekly runoff from each container was 3.5 L. Apparently, the amount of water runoff greatly increased as the daily application rate increased.

Figure 3 shows the average weekly amount of nitrogen (N), phosphate (P) and potassium (K) leached in water runoff samples and irrigation water samples collected between July 9 and August 5. During this period of time, the average total amount of weekly water runoff from 50 potting containers was 38.4 L, while the total amount of water applied to 50 trees was 814 L per week. The ratio of the nutrition leaching level based on its concentration in irrigation water was 1.8 for nitrogen, 1.6 for phosphate, and 12.5 for potassium.

Soil moisture content averaged 47% at the time just after irrigation and dropped to 33% before the next irrigation. Soil temperature was between 20°C and 24°C during day and night when daily irrigation was applied. The average tree caliper increased from 1.4 cm to 2.1 cm between July 3 and September 17.

Further data analysis will include the annual water runoff and nutrition leaching level due to irrigation and rainfall, irrigation water use efficiency, tree size responding to variations of soil moisture and temperature due to changes in weather conditions. After multi-test results are obtained, we will determine if there are potential techniques to enable automatic irrigation scheduling for pot-in-pot tree nurseries to optimize tree productions with minimal water consumption and nutrient and pesticide leaching.

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Disclosures

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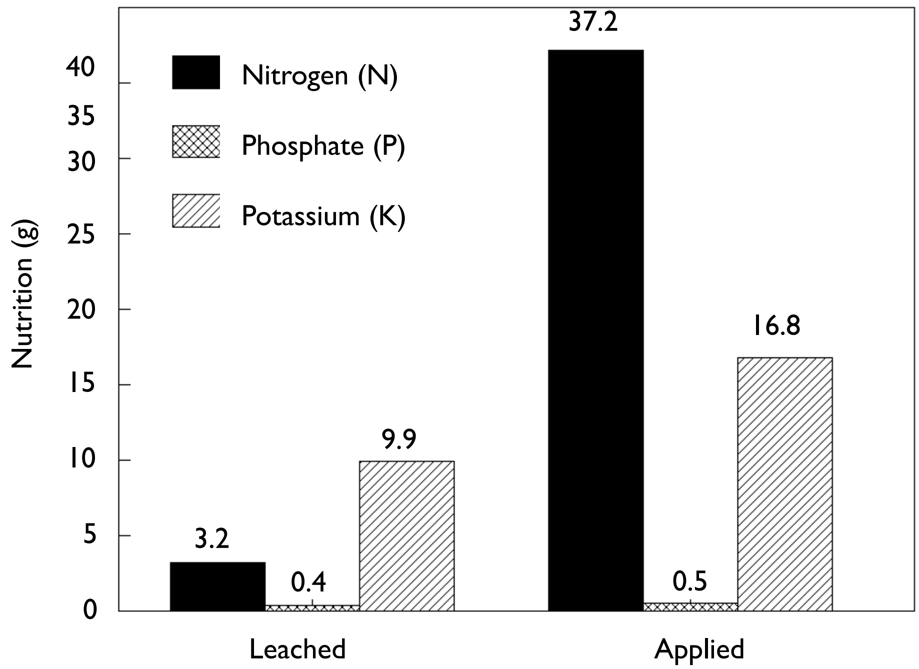

Figure 3. Average weekly nutrition leached and applied to five potting containers between July 9 and August 5.

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